

TITLE

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Hogg, J.S; Hopker, J.G; Coakley, S.L; et al.

JOURNAL

European Journal of Applied Physiology

DATE DEPOSITED

7 September 2020

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Hogg, James S. and Hopker, James G. and Coakley, Sarah Louise and Mauger, Alexis R. (2018) Prescribing 6-weeks of running training using parameters from a self-paced maximal oxygen uptake protocol. European Journal of Applied Physiology . ISSN 1439-6319. (In press)

DOI

<https://doi.org/10.1007/s00421-018-3814-2>

Link to record in KAR

<http://kar.kent.ac.uk/65903/>

Document Version

Author's Accepted Manuscript

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'Prescribing 6-wk of running training using parameters from a self-paced maximal oxygen uptake protocol'

Original Investigation

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Abstract Word Count: 238

Text-Only Word Count: 3,736

Tables (3); Figures (2)

This manuscript is available as Gold Open Access from the European Journal of Applied Physiology: <https://link.springer.com/journal/421>

37 **ABSTRACT**

38 **Purpose:** The self-paced maximal oxygen uptake test (SPV) may offer effective
39 training prescription metrics for athletes. This study aimed to examine whether
40 SPV-derived data could be used for training prescription. **Methods:** Twenty-four
41 recreationally active male and female runners were randomly assigned between
42 two training groups: (1) Standardised (STND) and (2) Self-Paced (S-P).
43 Participants completed 4 running sessions a week using a global positioning
44 system-enabled (GPS) watch: 2 x interval sessions; 1 x recovery run; and 1 x
45 tempo run. STND had training prescribed via graded exercise test (GXT) data,
46 whereas S-P had training prescribed via SPV data. In STND, intervals were
47 prescribed as 6 x 60% of the time that velocity at $\dot{V}O_{2max}$ ($v\dot{V}O_{2max}$) could be
48 maintained (T_{max}). In S-P, intervals were prescribed as 7 x 120 s at the mean
49 velocity of rating of perceived exertion 20 ($vRPE20$). Both groups used 1:2
50 work:recovery ratio. Maximal oxygen uptake ($\dot{V}O_{2max}$), $v\dot{V}O_{2max}$, T_{max} , $vRPE20$,
51 critical speed (CS), and lactate threshold (LT) were determined before and after
52 the 6-week training. **Results:** STND and S-P training significantly improved
53 $\dot{V}O_{2max}$ by $4 \pm 8\%$ and $6 \pm 6\%$, CS by $7 \pm 7\%$ and $3 \pm 3\%$; LT by $5 \pm 4\%$ and $7 \pm$
54 8% , respectively (all $P < 0.05$), with no differences observed between groups.
55 **Conclusions:** Novel metrics obtained from the SPV can offer similar training
56 prescription and improvement in VO_{2max} , CS and LT compared to training derived
57 from a traditional GXT.

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77 **KEY WORDS:** Recreational runners, Running performance, Critical Speed,
78 Endurance Training, Lactate Threshold

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80 **ABBREVIATIONS:**

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82	ANOVA	Analysis of variance
	CS	Critical speed
83	GPS	Global positioning system
	GXT	Graded exercise test
84	HR_{max}	Maximal heart rate
85	LT	Lactate threshold
	LT1	Lactate threshold 1
86	LT2	Lactate threshold 2
	RER	Respiratory exchange ratio
87	RER_{max}	Maximal respiratory exchange ration
88	RPE	Rating of perceived exertion
	RPE_{max}	Maximal rating of perceived exertion
89	STND	Standardised
	S-P	Self-paced
90	SPV	Self-paced $\dot{V}O_{2max}$ test
91	T_{max}	Time in which $v\dot{V}O_{2max}$ can be maintained
	V_E_{max}	Maximal minute ventilation
92	VCO₂	Carbon dioxide production
	$\dot{V}O_2$	Oxygen uptake
93	$\dot{V}O_{2max}$	Maximal oxygen uptake
94	$v\dot{V}O_{2max}$	Velocity at $\dot{V}O_{2max}$

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111 INTRODUCTION

112 The graded exercise test (GXT) is a globally recognised test which offers valuable
113 information on key aerobic parameters such as maximal oxygen uptake ($\dot{V}O_{2\max}$),
114 and can be used to prescribe training for both elite athletes, and recreational
115 exercisers. Recently, a novel approach to the traditional GXT has been proposed,
116 termed the self-paced $\dot{V}O_{2\max}$ test (SPV), which consists of 5 x 2 min stages where
117 speed or power is freely adjusted by the participant based on rating of perceived
118 exertion (RPE) (Mauger and Sculthorpe, 2012; Borg, 1982). The SPV has been
119 applied across a wide range of exercise modalities and ergometry despite its
120 relative infancy (Mauger and Sculthorpe, 2012; Chidnok et al. 2013; Straub et al.
121 2014; Hogg et al. 2015; Jenkins et al. 2017b; Lim et al. 2016; Scheadler and
122 Devor, 2015).

123 The general consensus from published research to date suggests that the SPV
124 provides comparable $\dot{V}O_{2\max}$ values to the GXT (Chidnok et al. 2013, Hogg et al.
125 2015; Lim et al. 2016; Scheadler and Devor, 2015; Straub et al. 2014; Faulkner et
126 al. 2015; Hanson et al. 2016), however the methodological differences and
127 contrasting populations used may make direct comparisons between studies
128 challenging. Higher $\dot{V}O_{2\max}$ values have been observed within the SPV test
129 (Mauger and Sculthorpe, 2012; Jenkins et al. 2017b; Jenkins et al. 2017a; Astorino
130 et al. 2015; Mauger et al. 2013), although all but one of these studies were cycling-
131 based. However, the findings regarding differences in $\dot{V}O_{2\max}$ are less meaningful
132 in terms of the utility of the test, with perhaps greater emphasis being placed on
133 the practical advantages that the SPV has over the GXT. The problems associated
134 with the GXT are well documented (Noakes, 2008), such as the incremental fixed-
135 intensity nature of the test, unknown test duration, and creating a test environment
136 that is possibly unnatural and irrelevant for “real” sporting performance. It has
137 therefore been put forward that the SPV may represent a paradigm shift in $\dot{V}O_{2\max}$
138 testing (Beltz et al. 2016), with self-paced protocols offering greater ecological
139 validity due to the self-paced and closed-loop nature, whilst also circumventing
140 the issue of estimating the ramp-rate and starting work rate for the researcher or
141 practitioner (Poole and Jones, 2017).

142 The GXT offers additional metrics in addition to the measurement of $\dot{V}O_{2\max}$, such
143 as the velocity at $\dot{V}O_{2\max}$ ($v\dot{V}O_{2\max}$) and the time in which $v\dot{V}O_{2\max}$ can be
144 maintained (T_{\max}). However, the identification of T_{\max} requires an additional test
145 which adds to the impracticality of the GXT. Nevertheless, $\dot{V}O_{2\max}$, $v\dot{V}O_{2\max}$ and
146 T_{\max} have been shown to be useful and viable parameters in running training and
147 performance (Billat and Koralsztein, 1996; Esfarjani and Laursen, 2007; Manoel
148 et al. 2017; Smith et al. 2003) and can be used to prescribe training and assess
149 training adaptation. If similar metrics for training prescription could be acquired
150 from the SPV, in a singular test, it would demonstrate utility over and above
151 traditional GXT assessment of $\dot{V}O_{2\max}$, especially as the SPV is an effective test
152 for highly trained runners (Hogg et al. 2015; Scheadler and Devor, 2015), and has
153 good test-retest reliability (Jenkins et al. 2017a). In addition, the SPV has recently
154 been validated as a field test (Lim et al. 2016), which increases its accessibility to
155 a variety of athletes and coaches. Therefore, the ability to prescribe training from
156 the SPV would enhance the value and utility of the test. As such, this study aimed
157 to investigate whether training prescribed via novel metrics derived from the SPV
158 could result in comparable improvements in key aerobic parameters as training
159 formulated from traditional GXT variables.

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161 MATERIALS AND METHODS

162 Participants

Twenty-four recreationally active male ($n = 16$) and female runners ($n = 8$) (Mean \pm SD: Age = 30 ± 9 years, body mass = 70 ± 13 kg, height = 172 ± 9 cm) volunteered to participate in this study. Sample size was estimated from power calculations (G-Power software, Franz Faul, Universitat Kiel, Germany) with mean and SD data from a similar training study (18). The study was conducted with the approval of the Ethics Committee of the School of Sport and Exercise Sciences at the University of Kent (Approval reference: Prop01.2014-15). All participants who volunteered read and signed a form of written informed consent before participation.

Exercise Tests

Participants were randomly allocated into two groups: 'Standardised' (STND) and 'Self-paced' (S-P). All participants completed a GXT, an SPV, and a sub-maximal lactate threshold (LT) test on a motorised treadmill (Saturn, HP Cosmos, Nussdorf-Traunstein, Germany), and a critical speed (CS) test as part of baseline testing on three separate occasions over a two wk period. The $\dot{V}O_{2\max}$ protocols were completed in a randomised order, 2-7 days apart and at the same time of day (± 2 h). Oxygen uptake ($\dot{V}O_2$) (Metalyzer 3BR2, Cortex, Leipzig, Germany) and heart rate (T31, Polar Electro Inc, New York, USA) were recorded for the duration of the testing protocol. The online gas analysis system was calibrated prior to every test in accordance with the manufacturer's guidelines. Before each test, participants performed a warm-up of their choice on the motorised treadmill, which was kept the same for all subsequent tests. The CS test was completed on an all-weather synthetic 400 m running track using the method outlined by Galbraith (2011). Briefly, this involved three runs at distances of 3600 m, 2400 m, and 1200 m, each separated by 30 min recovery. For the lactate threshold (LT) protocol, participants completed 4 min stages on the treadmill with a capillary blood sample (Biosen C-Line, EKF Diagnostics, Barleben, Germany) taken at the end of each stage, with the velocity increasing by $1 \text{ km}\cdot\text{h}^{-1}$ at the beginning of each stage. Starting speed was estimated based on each participant's individual fitness level. The test was terminated once lactate threshold 1 (LT1) and lactate threshold 2 (LT2) had been obtained, defined as blood lactate readings of 2 and $4 \text{ mmol}\cdot\text{L}^{-1}$, respectively. Before each test, participants were instructed to maintain similar eating habits, abstain from alcohol (24 h) and caffeine (8 h), and to avoid exhaustive or vigorous exercise (48 h). These conditions were verbally verified by the experimenter at each test visit. Following baseline testing all participants then undertook a 6 wk field-based training program, consisting of two high intensity interval training sessions, one recovery run, and a tempo run per wk. Training sessions were either based on data from the SPV or GXT [depending on group allocation]. Participants completed either a GXT, or SPV mid-training [depending on group allocation] in the third wk of the training programme. This test replaced one of the high intensity sessions for that wk, with its sole purpose to recalibrate interval session intensity in both groups. All baseline tests were then repeated in the immediate two-weeks that followed the 6 wk training intervention.

Graded Exercise Test (GXT)

The test commenced at a submaximal speed, gauged by the experimenter and subject, to help bring about volitional exhaustion within 8-12 min. Speed was increased by $1 \text{ km}\cdot\text{h}^{-1}$ every 2 min and the test was terminated when participants reached volitional exhaustion. Treadmill gradient was set to 1%. All previously described cardiorespiratory measures were recorded during this stage and participants continued until volitional exhaustion. 6-20 RPE² was recorded 20 s

215 before the end of each stage. Verbal encouragement was given throughout.
216 $\dot{V}O_{2max}$ was determined as the highest velocity that could be maintained for at
217 least 30 s (Smith et al, 2003).

218

219 Determination of T_{max}

220 For the GXT, the time that $\dot{V}O_{2max}$ could be maintained (T_{max}) was measured in
221 a separate bout of exercise (Smith et al. 2003). After a 20 min recovery (Nolan et
222 al. 2014) following the GXT, participants warmed up on the treadmill at 60%
223 $\dot{V}O_{2max}$ for 5 min. Participants were then allowed to stretch before remounting
224 the treadmill with the speed being ramped up over 30 s until $\dot{V}O_{2max}$ was reached.
225 Participants were then asked to continue until volitional exhaustion. Heart rate
226 and expired gas were recorded throughout this test.

227

228 Self-Paced $\dot{V}O_{2max}$ Test

229 The SPV was completed as previously described by Hogg and colleagues (2015).
230 Briefly, the SPV consisted of 5 x 2 min continuous stages with RPE increments
231 of 11, 13, 15, 17 and 20. A zonal pacing system was used where the researcher
232 would adjust the running speed based on the participant's positioning on the
233 treadmill. Participants were informed about the self-pacing zones before the
234 warm-up and then practiced moving between the zones after completing their
235 individualised warm-up. Familiarisation of the 6-20 RPE scale and how to vary
236 their speed according to a fixed RPE was provided via verbal explanation prior to
237 the warm-up with specific emphasis given to considering their RPE for each given
238 moment.

239

240 Determination of $\dot{V}O_{2max}$

241 Averaging of $\dot{V}O_2$ during GXT and SPV tests was performed over 30 s. $\dot{V}O_{2max}$
242 in the GXT and SPV was defined as the highest $\dot{V}O_2$ averaged for 30 seconds. A
243 plateau in $\dot{V}O_2$ during the GXT was accepted if the change in $\dot{V}O_2$ during the
244 highest 30 s average from each of the final two stages of the test were less than
245 half of the normal stage-to-stage difference in $\dot{V}O_2$ during the initial linear parts
246 of the test for each subject²³. As an ancillary method to verify attainment of
247 $\dot{V}O_{2max}$, secondary criteria were accepted when two of the following were
248 attained: Heart rate (HR) within 10 bpm of age-predicted maximum; Respiratory
249 exchange ratio (RER) ≥ 1.15 and RPE ≥ 17 .

250

251 Training programme

252 All participants completed two high-intensity interval sessions per week, along
253 with a recovery run and a tempo run. This equated to four exercise sessions per
254 week. Participants were free to schedule the sessions throughout each week but
255 were encouraged to not complete interval sessions and tempo run on consecutive
256 days. All sessions were completed using an assigned global positioning system
257 (GPS) watch (310XT, Garmin International Inc, KS, USA), and training was
258 logged in a training diary

259

260 STND Group

261 For each interval session, participants completed 6 intervals at $\dot{V}O_{2\max}$ with
262 duration determined as 60% of T_{\max} (Smith et al. 2003). A 2:1 ratio was used to
263 determine the recovery stage duration in-between each interval. Recovery run
264 intensity was calculated as 60% of their maximal heart rate (HR_{\max}) obtained from
265 the GXT. Participants were required to run for 30 min. This session was included
266 to help ensure participants would not be encouraged to supplement their program
267 with additional training.

268 Tempo run intensity was determined from the submaximal LT test and
269 participants were required to run at a velocity calculated as 50% between LT1 and
270 LT2 for 30 min.

271

272 S-P Group

273 For each interval session, participants completed 7 x 2 min intervals at a velocity
274 corresponding to the mean velocity completed during the final (RPE20) stage of
275 the SPV. A 2:1 ratio was used to determine the recovery stage duration in-between
276 each interval. The recovery run was the same as in the STND group, but intensity
277 was calculated as 60% of their HR_{\max} obtained from the SPV.

278 Tempo run intensity was determined by calculating the ventilatory threshold (VT)
279 via the V-Slope method from the $\dot{V}O_2$ and $\dot{V}CO_2$ data collected during the SPV
280 (Beaver et al. 1986). The participants were then asked to run at an RPE that
281 corresponded with the stage of the SPV in which the VT was achieved. The
282 participants were asked to freely adjust their pacing to match the required RPE.

283

284 Statistical Analysis

285 Prior to statistical analysis, data were checked and confirmed to be normally
286 distributed. A paired samples t-test was performed to assess maximal value
287 differences between protocols. Based on the achieved effect size, a post hoc power
288 analysis demonstrated that the statistical power of the pre-post $\dot{V}O_{2\max}$ comparison
289 was 0.93. To identify training responses for both training groups (group) and GXT
290 and SPV protocols (protocol) for before and after training (time-point) a mixed
291 model analysis of variance (ANOVA) was used. Where no interaction effect was
292 identified between a variable and protocol (GXT and SPV), the protocol was
293 omitted from further analysis of training responses for that variable. Participants'
294 CS were calculated from the field test using a linear distance-time model. Partial
295 eta-squared (η_p^2) was used to report effect sizes, and statistical significance was
296 accepted when $P < 0.05$. All statistical tests were completed using SPSS version
297 24 (Chicago, IL, USA).
298

299 RESULTS

300 SPV vs. GXT Protocol Data

301 Incidence of $\dot{V}O_2$ plateau in GXT and SPV Protocols

302 The average stage-to-stage increase in $\dot{V}O_2$ for all participants was calculated as
303 $393 \pm 21 \text{ mL} \cdot \text{min}^{-1}$, so that a plateau phenomenon was defined as a change in $\dot{V}O_2$
304 $\leq 197 \pm 10 \text{ mL} \cdot \text{min}^{-1}$ (or relative $\dot{V}O_2$ $2.8 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), between the highest 30
305 s average obtained from each of the final two stages of the test for each participant.
306 All participants achieved either a $\dot{V}O_2$ plateau or satisfied secondary criteria
307 across both GXT trials before and after training. Ninety-three percent of

308 participants satisfied secondary criteria across both SPV trials before and after
309 training.

310

311 Differences in test protocols

312 Differences in test protocols for key variables for all participants are presented in
313 Table 2. Pre and post-training data were combined to compare the GXT and SPV
314 protocols. There were no significant differences in $\dot{V}O_{2\max}$ between the GXT and
315 SPV protocols ($P = .578$). Maximal RER (RER_{\max}) was significantly greater in
316 the SPV compared to the GXT ($P < .001$). There was no interaction effect between
317 test protocol for either HR_{\max} or maximal minute ventilation ($V_{E\max}$) ($P = .212$; P
318 $= .319$, respectively). Protocol duration was significantly longer in the GXT ($P <$
319 $.001$). RPE_{\max} was significantly greater in the SPV ($P < .001$). There were no
320 significant differences between the velocities associated with $\dot{V}O_{2\max}$ and RPE_{20}
321 ($P = .130$).

322

323 STND vs. S-P Training Data

324 Training prescription

325 Total prescribed training duration over the 6 wk period for both training groups
326 was not significantly different ($P = .651$). The STND had a prescribed total
327 duration of 804 ± 90 min whilst the S-P had a prescribed total duration of $816 \pm$
328 0 min. There was no significant difference between the mean interval session
329 duration for both STND and S-P (37 ± 8 vs 38 ± 0 min, respectively) ($P = .679$).

330

331 Enter Table 1 here:

332

333 Responses to Training

334 Group data (pre- vs. post-training) are shown in table 3. As outlined in the
335 methods, participants were grouped into either S-P or STND, and conducted both
336 an SPV and GXT before and after the training intervention. There was no
337 interaction effect for protocol duration between time-point, protocol and group
338 ($F_{1,22} = .561$, $P = .462$, $\eta_p^2 = .025$). As shown in Figure 1 and Table 3, there was
339 an interaction effect between $\dot{V}O_{2\max}$ and time-point ($F_{1,22} = 7.461$, $P = .012$, η_p^2
340 $= .253$) however there was no interaction effect observed between group and time-
341 point ($F_{1,22} = .003$, $P = .954$, $\eta_p^2 = .0001$). Whilst there was an interaction effect
342 between $V_{E\max}$ and time-point ($F_{1,22} = 12.592$, $P = .002$, $\eta_p^2 = .364$), there was no
343 interaction effect between time-point and group ($F_{1,22} = .001$, $P = .981$, $\eta_p^2 =$
344 $.0001$). There was no interaction effect for HR_{\max} between time-point and group
345 ($F_{1,22} = 1.063$, $P = .314$, $\eta_p^2 = .046$).

346 There was an interaction effect between time-point and running velocity at
347 $\sqrt{RPE_{20}}$ and $\sqrt{\dot{V}O_{2\max}}$ ($F_{1,20} = 5.800$, $P = .026$, $\eta_p^2 = .225$). As shown in figure 2,
348 for both groups there were no differences in $\sqrt{\dot{V}O_{2\max}}$ and $\sqrt{RPE_{20}}$ before training

(14.3 + 1.3 km·h⁻¹ vs. 14.3 + 1.7 km·h⁻¹, respectively), but $\sqrt{\text{RPE20}}$ was greater than $\sqrt{\text{VO}_{2\text{max}}}$ after training (15.7 + 1.3 km·h⁻¹ vs. 15.2 + 1.3 km·h⁻¹, respectively). CS improved in both groups ($P < .001$) however there was no interaction effect between time-point and group ($F_{1,21} = 3.006$, $P = .098$, $\eta_p^2 = .125$). Similarly, LT1 and LT2 improved in both groups ($F_{1,21} = 14.637$, $P < .001$, $\eta_p^2 = .411$) however there was no interaction effect between time-point and group ($F_{1,21} = 1.227$, $P = .281$, $\eta_p^2 = .055$).

DISCUSSION

The primary finding of this study was that following a 6 wk period of training, recreational runner's aerobic fitness and running performance was increased by a similar magnitude, regardless of whether SPV or GXT data were used to prescribe training. Specifically, $\sqrt{\text{VO}_{2\text{max}}}$ in the STND group improved by 4%, and by 6% in the S-P group. An improvement in $\sqrt{\text{VO}_{2\text{max}}}$ in the region of ~3% has previously been defined as a meaningful improvement in performance (Kirkeberg et al, 2010), as opposed to day-to-day variation. Previous literature has shown improvements in $\sqrt{\text{VO}_{2\text{max}}}$ by ~6% when training at 106% $\sqrt{\text{VO}_{2\text{max}}}$ (Franch et al, 1998) for similar training durations. However, in the aforementioned study the starting $\sqrt{\text{VO}_{2\text{max}}}$ for the participants were significantly lower than those reported in the current study, which may suggest a greater level of trainability for $\sqrt{\text{VO}_{2\text{max}}}$ (Swain and Franklin, 2002) compared with the participants in the current study. Athletes of slightly higher training status' than those in the current study achieved little to no improvements in $\sqrt{\text{VO}_{2\text{max}}}$ over 4-6 weeks of similar intensity training (Manoel et al. 2017; Smith et al. 2003; Denadai et al. 2006), but did show significant improvements in LT and 3-10 km running performance. Similar running programmes utilising interval training have also produced improvements in CS (Esfarjani and Laursen, 2007). This is supported by the findings of the current study that in both STND and S-P, CS improved by 7% and 3%, respectively. For LT1 and LT2, STND improved by 5% and 3% and S-P improved by 7% and 8%.

An important finding of this study is that the novel training parameter extracted from the SPV, ' $\sqrt{\text{RPE20}}$ ', is effective at prescribing running intensity for interval training. The $\sqrt{\text{VO}_{2\text{max}}}$ for the STND before and after training was 14.3 ± 0.9 vs. 15.2 ± 1.0 km·h⁻¹ compared to the S-P's $\sqrt{\text{RPE20}}$ of 14.2 ± 1.9 vs. 15.7 ± 1.9 km·h⁻¹ respectively. It is likely that the $\sqrt{\text{RPE20}}$ may reflect a speed between $\sqrt{\text{VO}_{2\text{max}}}$ and the maximal velocity achieved in a GXT (V_{max}). V_{max} has recently been shown to be as beneficial as $\sqrt{\text{VO}_{2\text{max}}}$ for exercise prescription (Manoel et al. 2017), and like $\sqrt{\text{RPE20}}$ is simple to calculate. Moreover, $\sqrt{\text{RPE20}}$ has been shown to be repeatable regardless of the pacing strategy adopted during this final stage (Hanson et al. 2017). This should be reason to encourage further investigation to assess the potential of $\sqrt{\text{RPE20}}$ in training prescription and its suitability as a performance parameter.

As the aim of the study was to investigate whether SPV-derived training parameters could offer similar improvements in aerobic fitness compared to GXT prescribed training, it was important that training prescription was similar between groups in both intensity and duration. To calculate interval duration for the STND, 60% T_{max} was used. Setting interval duration at 60% of an individual's T_{max} has been shown to produce significant improvements in aerobic parameters and 3-10 km running performance (Esfarjani and Laursen, 2007; Manoel et al. 2017; Smith et al. 2003). In the study by Smith and colleagues (2003), 60% T_{max}

399 resulted in an average interval duration of $6 \times 133.4 \pm 4.1$ s. This equated to ~13
400 min of high intensity effort per interval session. In the current study, 7 intervals
401 at 120 s [which also matched the stage duration of the SPV] resulted in ~14 min
402 of high intensity effort, ensuring it was comparable to the STND group. Durations
403 of 2 min have been shown to elicit responses closer to $\dot{V}O_{2\max}$ compared to shorter
404 intervals (O'Brien et al. 2008). Longer interval work periods may have resulted in
405 a greater $\dot{V}O_{2\max}$ improvement (Esfarjani and Laursen, 2007; O'Brien et al. 2008;
406 Seiler and Sjaursen, 2002) but also significantly increased the interval duration. As
407 a consequence, the mean prescribed training duration for each interval session
408 over the 6 wk training period was similar between groups (37 ± 8 vs 38 ± 0 min
409 for STND and S-P, respectively). Total training time over the 6-week period was
410 also similar (804 ± 90 vs 816 ± 0 min, for STND and S-P respectively).

411 The similar $\dot{V}O_{2\max}$ found between both protocols in this study is in line with
412 previous research (Chidnok et al. 2013; Hogg et al. 2015; Lim et al. 2016;
413 Scheadler and Devor, 2015; Straub et al. 2014; Faulkner et al. 2015; Hanson et al.
414 2016). Even though test duration was significantly longer in the GXT, the test still
415 fell within the recommended duration of 8-12 minutes (Yoon et al. 2007), and the
416 $\dot{V}O_{2\max}$ achieved was not significantly different between protocols. Interestingly,
417 RER_{\max} was significantly higher in the SPV, which has been observed in some
418 (Mauger and Sculthorpe, 2012; Hogg et al. 2015; Jenkins et al. 2017b), but not all
419 previous SPV literature (Lim et al. 2016; Straub et al. 2014; Faulkner et al. 2015;
420 Astorino et al. 2015). Consequently, no consensus on whether the SPV produces
421 a higher RER_{\max} can be currently drawn. However, the authors speculate that this
422 potential difference in RER_{\max} may be due to the higher peak velocities
423 experienced in the SPV compared to the GXT, indicative of a greater anaerobic
424 contribution towards the end of the test. This is supported by the recent work of
425 Hanson and colleagues (2017) who found, when comparing two SPV trials with
426 different RPE20 pacing strategies, that RER_{\max} was significantly greater in the
427 SPV that adopted the more aggressive pacing strategy.

428

429 CONCLUSIONS

430 The ability to prescribe training for recreationally active males and females via
431 SPV-derived parameters offers coaches and athletes valuable alternatives to
432 traditional methods. Prescribing training via the SPV is as effective but more time-
433 economical. Specifically, the same level of improvement in key aerobic fitness
434 parameters can be obtained when training is set via novel training parameters
435 collected from a single 10 min SPV test compared to that achieved using a GXT
436 and a mandatory additional test to acquire T_{\max} data. This alone may make the
437 SPV more attractive to athletes and coaches, however, recent research regarding
438 a field based SPV (Lim et al. 2016) may emphasise this further. Whilst a field-
439 based SPV has been shown to produce a valid directly measured $\dot{V}O_{2\max}$, future
440 research should investigate whether $\dot{V}O_{2\max}$ can be accurately estimated from the
441 field based SPV. If so, athletes and coaches would then be able to utilize a single
442 10 min test on an athletics track, without expensive equipment, that would offer
443 accurate $\dot{V}O_{2\max}$ estimation and data for effective training prescription. Therefore,
444 the current findings demonstrate that training parameters derived from the SPV
445 protocol can be used to prescribe effective running training that is similarly
446 effective to training prescribed from GXT-derived parameters. Consequently, in
447 the group that was prescribed training using SPV-derived parameters, $\dot{V}O_{2\max}$,
448 LTs and CS showed similar improvements compared to runners who were
449 prescribed training via the velocity at $\dot{V}O_{2\max}$ and LT zones, with training durations
450 and intensities suitably similar between groups throughout training.

451

452 **ACKNOWLEDGEMENTS**

453 Adam Hart, Francesca Waters, Marcus Cram, and Stewart Clayton for their
454 assistance with data collection.

455

456 **CONFLICT OF INTEREST**

457 None

458

459 All procedures performed in studies involving human participants were in
460 accordance with ethical standards of the institutional and/or national research
461 committee and with the 1964 Helsinki declaration and its later amendments or
462 comparable ethical standards.

463

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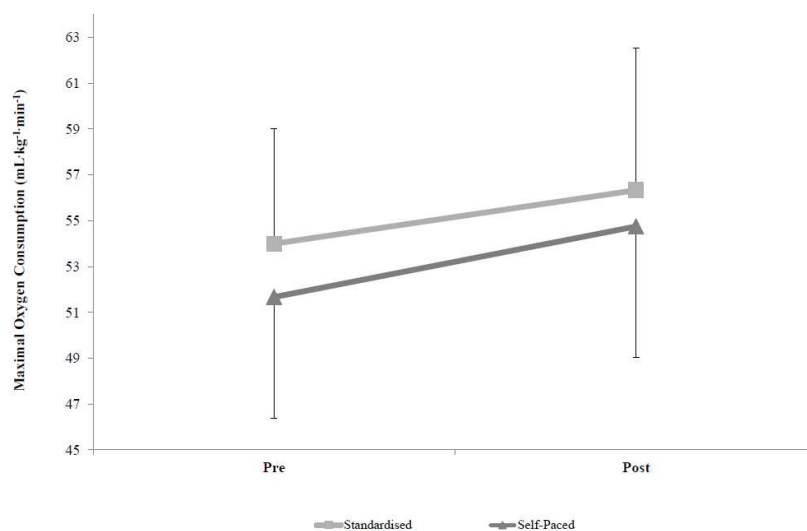
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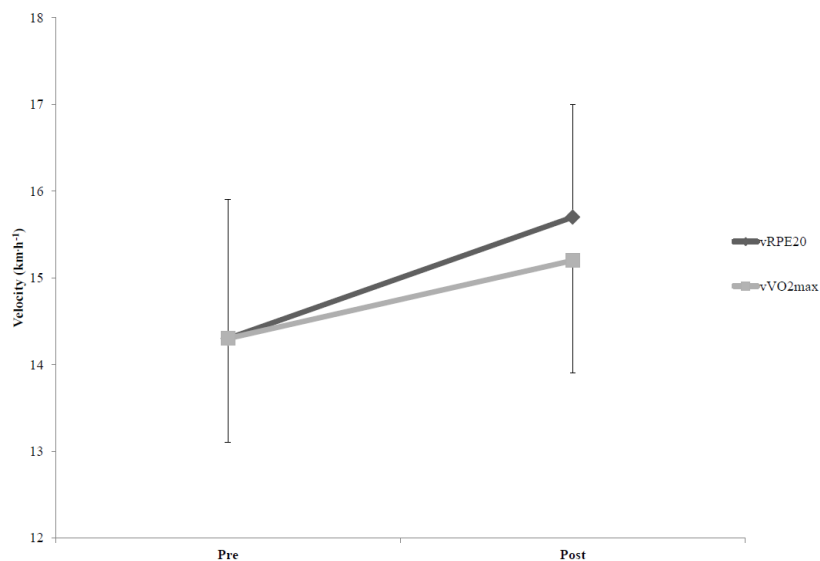
587 **Figure Legends**

588 **Figure 1.** Mean \pm SD Differences in $\text{VO}_{2\text{max}}$ between the STND and S-P
 589 training groups before and after training.



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591 **Figure 2.** Mean \pm SD Differences in the velocities $v\text{VO}_{2\text{max}}$ and $v\text{RPE20}$ for all
 592 participants for before and after training.



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600 **Table 1.** Training prescription for a representative subject in both training
601 groups.

Rep. Subject	Training Prescription			
	Interval session x 2		Tempo Run	Recovery Run
	Weeks 1-3	Weeks 4-6	Weeks 1-6	Weeks 1-6
STND	Work: 6 x 167 s @ 15 km·h ⁻¹ Recovery: 5 x 334 s @ 8 km·h ⁻¹	Work: 6 x 141 s @ 16 km·h ⁻¹ Recovery: 5 x 282 s @ 8 km·h ⁻¹	30 min @ 11.3 km·h ⁻¹	30min @ 115 bpm
S-P	Work: 7 x 120 s @ 15.6 km·h ⁻¹ Recovery: 6 x 240 s @ 8 km·h ⁻¹	Work: 7 x 120 s @ 16.3 km·h ⁻¹ Recovery: 6 x 240 s @ 8 km·h ⁻¹	30 min @ RPE13	30 min @ 114 bpm

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603 STND = Standardised training group, S-P = Self-paced training group

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627 **Table 2.** Mean \pm SD peak values for physiological and intensity variables
 628 recorded during both GXT and SPV protocols across both before and after
 629 training for all participants.

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Variable	Protocol	
	GXT	SPV
$\dot{V}O_{2\max}$ (mL·kg ⁻¹ ·min ⁻¹)	54 \pm 5.8	54 \pm 0.7
HR _{max} (beats/min)	186 \pm 12	184 \pm 11
V _E _{max} (L/min)	135.4 \pm 29.4	137.2 \pm 24.8
RER _{max}	1.15 \pm 0.02	1.21 \pm 0.00*
$\dot{V}O_{2\max} / \dot{V}RPE_{20}$ (km·h ⁻¹)	14.8 \pm 1.3	15 \pm 1.5
Mean test time (min)	11 \pm 1*	10 \pm 0
RPE _{max}	19 \pm 1	20 \pm 0*

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632 *Denotes significant difference within the group for the given variable between
 633 pre and post testing (p<0.05).

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654 **Table 3.** Mean \pm SD maximal values for physiological and threshold variables
655 recorded before and after training for both training groups. In the STND all data
656 is provided via the GXT and by the SPV for the S-P.

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Variable	Training Group			
	Standardised (STND)		Self-Paced (S-P)	
	Pre	Post	Pre	Post
$\dot{V}O_{2\max}$ (mL \cdot kg $^{-1}\cdot$ min $^{-1}$)	54 \pm 5.0	56.3 \pm 6.2*	51.7 \pm 5.3	54.8 \pm 5.7*
$V_{E\max}$ (L/min)	130.2 \pm 22.6	134.7 \pm 20.4*	134.3 \pm 28.7	141.5 \pm 29.0*
HR_{\max} (beats/min)	190 \pm 13	188 \pm 13	181 \pm 13	182 \pm 9
Critical speed (m.s $^{-1}$)	3.47 \pm .03	3.70 \pm .03*	3.47 \pm .04	3.59 \pm .05*
LT1 (km \cdot h $^{-1}$)	10 \pm 1.2	10.5 \pm 1.2*	9.7 \pm 1.5	10.5 \pm 1.3*
LT2 (km \cdot h $^{-1}$)	11.7 \pm 1.2	12.2 \pm 0.8*	11.1 \pm 1.8	12.1 \pm 1.5*

659

660 *Denotes significant difference within the group for the given variable between
661 pre and post testing (p<0.05).